MODERN METHODS OF SEWAGE DISPOSAL

W. H. TRENTHAM & J. SAUNDERS

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A PRACTICAL HANDBOOK FOR THE
USE OF MEMBERS OF LOCAL AUTHORITIES
AND THEIR OFFICIALS

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PREFACE

THE experience of twenty years in the design, construction, and practical management of sewage disposal works has enabled us to put before the reader, interested in such problems, a condensed account of Modern Methods of Sewerage and Sewage Disposal. The members of local authorities and their officials, who are as a rule active business men, usually have no time to study elaborate treatises, when it is necessary for their Boards to undertake the construction of such works, and we believe that the information herein given, based entirely on practical acquaintance with the subject, will prove of value in assisting them to decide which system of sewerage and sewage disposal should be adopted to meet the requirements of their particular town or district.

The standard of sanitation is daily increasing, and it behoves every local authority to seriously consider how they can best keep their districts abreast of the times. An insanitary town depletes the vitality of its inhabitants, keeps desirable residents away, and is indirectly a financial loss to the community. The expenditure incurred on laying sewers, constructing sewage disposal works, and perfecting the sanitary condition of towns is not, as is sometimes

imagined, entirely unremunerative, the result always being healthier homes, less epidemical disease, a stronger and more vigorous people, a lower death-rate, and a general addition to the comfort and welfare of the inhabitants of the district.

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CONTENTS

LIST OF ILLUSTRATIONS

MODERN METHODS OF SEWAGE DISPOSAL

INTRODUCTION

THE sewerage of towns and villages has developed from a hap-hazard construction of stone culverts and brick sewers —too large as a rule to take the flow—laid in an irregular manner, following the curvature and gradients of the streets, liable to stoppages and the retention of effete matters, dangerous to health, and the primary cause of epidemic diseases. Sanitary engineers, when laying out a scheme of sewerage, now carefully calculate, from data founded on long experience, the dimensions of the sewers necessary to carry off both liquid and solid matters as quickly as possible. It may appear to the lay mind to be a simple matter to construct a system for a town or village; but the past has proved that a great amount of skill and experience is required to design one which will be economical, effectual in work, and efficiently ventilated in such a manner as not to be a nuisance to the inhabitants. Moreover, however well and carefully the design of a scheme be prepared, complete satisfaction cannot be obtained unless the engineer is careful to see that his plans are carried out in every detail. In one case, which

came under the notice of the authors, the sewers were constructed in such a manner that enormous quantities of subsoil water found access thereto. This not only caused the Corporation concerned a very considerable expenditure in relaying and reconstructing many portions of the system, but also involved them in a costly law-suit and extensive additions to the purification plant.

In former times, when sewage was disposed of on land, no scientific explanation of the reasons for the change in the organic matters had been evolved; but it is now known, with a great amount of exactitude, that the growth and development of biological life, and the micro-organisms in the soil, are responsible for the changes taking place when sewage is applied to land, and this knowledge has now been applied to the construction of "anaërobic" and "aërobic" artificial purification works. A considerable amount of definite knowledge has been accumulated, enabling artificial methods of propagation of the biological life to be developed under the best conditions for effecting the dissolution of the organic matters in sewage.

In the opinion of the authors—based on a number of years' actual experience of working bacterial and biological disposal plants which entailed making analyses, both bacteriological and chemical—it is necessary that the consulting engineer engaged on the construction of sewage disposal works should be conversant with every part of the management, as success lies, not only in the broad lines of laying out a scheme, but also in that attention to the minute details which can only be learnt by practical work.

"Biological," "bacteria," "microbes," "anaërobic," "aërobic," and other similar terms constantly occur in speaking of sewage works. To the active business man the use of these unfamiliar scientific words probably conveys

but little meaning, and this has induced the authors to explain them as clearly as possible.

Biological Filters are beds of artificial construction prepared to cultivate the lower forms of life, animal and vegetable, for the purpose of purifying sewage. The term biological embraces all living matter developing in the beds, such as worms, infusoria, bacteria, plants and other forms of life. The word is a derivative of *biology*, from two Greek words signifying "the course of life" and "a word." It was first introduced by Trevaranus of Bremen to describe the science which collects information systematically about all living beings, and classifies, compares, and deduces laws which explain their existence. It is the science of all life in its widest acceptation, including animal and vegetable, and embraces the sciences of zoology, botany, anthropology, anatomy, and physiology.

Microbes.—In 1878, Sedillot applied this name to any minute organism—vegetable or animal—which requires the aid of microscopic powers to make its form apparent to the eye; hence, "micro-organism," which has the same meaning as microbe. *Pathogenic microbes* are those which produce or generate disease. *Septic micro-organisms* are those particular species which cause putrefaction and blood-poisoning, thus "septic tank" means a tank constructed for developing the putrefactive microbes.

Bacteria is the name given to fungi, the minute organisms which either decompose or cause putrefaction in organic substances. They vary in size from one five-thousandth to one twenty-five-thousandth of an inch, and, when viewed under the highest microscopic powers, appear little larger than minute dots of ink on paper. They are of various forms, some being globular, others egg-shaped, the most common form being that of the jointed rod. They are

distributed indiscriminately all over the surface of the world, developing in various ways according to their environment, the great majority living in the superficial layers of decomposing plant and animal tissue.

Aërobic Bacteria live only in the presence of air, in contradistinction to the *anaërobic bacteria*, which only thrive in the absence of air. When air is present the aërobic organisms multiply with great profusion, and in obtaining sustenance convert the organic matters into simpler elements in an inoffensive manner. On the other hand, the anaërobic bacteria give off large quantities of objectionable gases when feeding on the organic matters and reducing them to simpler elements.

Infusoria, derived from a modern Latin word, signifying "to pour in, to infuse." Otto Frederick Müller first applied the name to the microscopic animalculæ developed in organic infusions. A drop of water from a weedy pool or ditch, or stale sewage, when viewed under the microscope, contains infusoria in countless numbers; some belong to the animal kingdom, some to the vegetable kingdom, while others are on the border-land between animals and plants.

Fresh crude sewage teems with microbes, bacteria, and the spores of infusoria of numerous different species, and in disposal works beds are constructed to cultivate them and increase their fecundity for the specific purpose of changing the organic constituents of the sewage into simple inoffensive elements. When sewage is admitted either into a contact bed or percolating filter, the organic matters in it adhere to the innumerable surfaces presented by the filtrant; the micro-organisms—known as microbes, bacteria, infusoria, and the other biological life—then commence to feed upon the organic matters present in the sewage and multiply with extraordinary prolificacy, so that each particle of filtrant is

very soon entirely encased with a coating of micro-organisms. After feeding, the admittance of air to the filter—which process is given the name of *aëration*—is necessary to the aërobic organisms, and it revivifies them, so that they may receive additional food by the application of a further dose of sewage. The alternations of feeding and aëration can proceed indefinitely so long as the proper conditions for the existence of the organisms are maintained.

Beds for the purification of sewage are referred to either as *contact beds*, which term designates a bed composed of some suitable medium for retaining bacteria, etc., such as slate, coke, clinker, or other convenient substances, placed in a tank so that by shutting a valve every portion of the medium can be immersed and brought in contact with the liquid which is to be purified; or as *percolating filters*, which are also known as continuous filters, flow filters, or trickling filters, on which the sewage is distributed over the upper surface in a fine spray, gradually trickling downwards over each particle of filtrant until the outlet drains are reached.

The words *sewage works* and *sewerage works* are frequently mis-used. The former term should only be applied to works constructed for the purification of sewage, the latter term to the sewers, manholes, and other works made for the conveyance of the sewage to the outfall.

The **Natural Purification** of sewage is understood to mean that it is treated either by filtration or broad irrigation on land. *Land filtration* is the concentration of sewage upon as small an area of land as it is possible to purify it on without excluding vegetation. *Land irrigation* consists of distributing the sewage over the whole area of the land in as thin a film as is compatible with completely wetting the surface, having in view a maximum growth of vegetation.

The **Artificial Purification** of sewage includes its treatment in tanks and on filters, either contact beds or by percolation.

In the natural purification of sewage, the microbes, bacteria, infusoria, and other biological life are the agents which ultimately change the organic matters causing the pollution. In artificial purification of sewage the beds are designed to cultivate this biological life for the specific purpose of changing the organic matters into simpler elements.

The **Nitrification** of sewage is the conversion of the organic substances into nitrogen and gases by the activity of the bacteria. Ammonia is one of the objectionable forms of pollution present in sewage; chemically it consists of one molecule of nitrogen and three molecules of hydrogen, this combination giving off a pungent and objectionable smell. Considerable quantities of ammonia are found in all sewage, which the micro-organisms attack, the hydrogen being liberated as a gas or combining with oxygen to form water, the nitrogen combining with oxygen and the alkalies, forming nitrates, or nitrites, which are salts of nitric and nitrous acid respectively in a non-putrefactive form, and in such a condition as to be readily assimilated by plant life.

Oxidation.—The most abundant of all substances in the world is oxygen. It forms one-fifth of the atmosphere, and eight-ninths of the water, by weight, every gallon of which, if pure, has about two cubic inches of oxygen dissolved in it. When water is polluted the organic matters present rob it of some of its free oxygen, the amount depending upon the degree of pollution. The various changes brought about by the biological life in polluted water tend to purify it, the bacteria absorbing oxygen, which the water dissolves from the atmosphere, and in the perform-

ance of their life functions cause this oxygen to combine with the organic substances, by various stages, until the water is again pure and fully oxidised.

Having cleared the way by defining the scientific nomenclature usually employed, the practical work of sewering towns and disposing of the sewage in a sanitary manner will now be described.

I

SEWERAGE SYSTEMS

In laying out the sewers of a town or village, it should first be determined if the plaee is to be sewered on the "separate" or "combined" system; that is to say, whether the storm or surfaee water is to be admitted to the main sewers, or run into a separate system construeted entirely for that purpose. In small towns and villages, and in the suburbs of larger towns, the "separate" system is advisable; the "eombined" system being generally used when the districts are so mueh congested that the street washings are virtually as polluted as the ordinary flow of sewage. In old towns, where there is already a system of sewers laid, these may frequently be adapted for carrying off the surface water, the new sewers being retained entirely for sewage proper. Even when a separate system is laid in towns, a eertain proportion of rain water will probably have to be admitted; usually this is confined to the washings from back yards and the roof water from the rear of the premises, which eannot be eonveniently carried into the storm sewer; and should pumping be required, it is advisable to limit the rainfall admitted to the sewers to the smallest quantity possible, in order to keep down the consequent eharges. The result of laying a "separate" system in a town is, that a large saving can be effected in the eost of the sewers and man-

holes, as well as a reduction in the capital expenditure upon the sewage purification works.

The amount of sewage will depend in a very great measure upon the density of the population, and whether it be a manufacturing or residential town. In rural districts this amount may be taken at from 15 to 30 gallons per head of population per day; in larger urban districts the quantity may amount to from 20 to 40 gallons per head of population per day. An approximation to the amount of sewage can always be obtained if the place has a public supply of water, the flow of sewage being usually equal to the public water supply.

In addition to the ordinary domestic sewage and the liquid refuse from the various trades in the district, there is also a proportion of rainfall which will find its way into the sewers, even if the place is sewered on the separate system. This is a very variable quantity, and in each district the records of any rain gauges available should be consulted to find the average and maximum rates of fall. A usual allowance is to provide for 2·6 inches of rainfall per day in large towns; 1·3 inches in small towns; and 1 inch per day in rural villages, half of this passing off in six hours. This rainfall must be taken over the whole area actually contributing to the sewers, which in a town sewered on the separate system would comprise the back roofs of houses and back yards; while in a town sewered on the combined system, it would also include the streets, front roofs, and fore-courts of premises in addition. The Local Government Board allow storm water exceeding six times the normal dry weather flow to be passed into a water-course without treatment, which practically means that all sewage disposal works have to treat six times the normal flow.

The sewers should be laid in straight lines from manhole

to manhole, and have even gradients between these points sufficient to always ensure self-cleansing velocities. In main outfall sewers where the sewage is always running at a considerable depth, the velocity may, in special cases, be as low as 2 feet per second; in other main sewers connecting up different districts, the velocity should not be less than $2\frac{1}{2}$ feet per second, while all the tributary sewers should be laid to falls to ensure a velocity of at least 3 feet per second. If the gradients of the sewers are such that the velocities will exceed 6 feet per second, means should be taken to check this velocity at the manholes, so that the inverts may not be damaged by the scour of the sewage.

The minimum depth at which the sewers should be laid will depend upon whether it is necessary to drain the basements (if any) in the district, the depth in this case being governed by the lowest basement; but, as a general rule, 10 feet from the surface of the road to the invert will be sufficient. In towns where there are no basements, this depth may be kept at 5 feet; but there are instances where it is sometimes advisable to lay the sewers at shallower depths than this, and then either iron pipes must be used, or the stoneware pipes be entirely encased with 6 inches of cement concrete. Where the depth of the sewers is more than 15 feet below the surface of the ground, and earthenware pipes are used, these should also be encased in not less than 6 inches of cement concrete.

The size of the sewers should be governed by the normal flow of sewage, the rainfall, and the gradient obtainable, the internal sectional area being carefully calculated from these data. An allowance should be made in towns which are rapidly extending, for a prospective increase in the amount of sewage; but, on the other hand, sewers too large in diameter retard the velocities of the sewage and give a great

amount of trouble through the deposition of solid matter on the inverts. No public sewer should be less in diameter than 6 inches.

For small sewers up to 24 inches in diameter, glazed earthenware socketed pipes should be used, these being either jointed in cement, or, if wet ground be encountered, one of the numerous patented double-jointed pipes are preferable, where, in addition to the cement joint, there is a plastic ring of bitumen. For larger sewers, brickwork built in cement should be used, the lower portion, where the wear is greatest, being constructed with blue Staffordshire bricks, the inverts being formed with specially made hard glazed stoneware blocks, which ensure a truer invert and a smoother channel for the passage of the sewage. The bricks used for the construction of sewers, manholes, and flushing chambers should be of a hard, durable character and impervious to moisture. Cement concrete has been extensively used for large sewers in towns, and it is an excellent material, but requires the most careful supervision during the period of construction to obtain reliable work. For sewers up to moderate dimensions, cast concrete pipes are now frequently used, and, if care be taken in the laying and jointing, they will give satisfaction.

Where it is necessary to pump the sewage, and in schemes where the purification works are designed to only treat the sewage during the day, storage capacity of some description must be provided. This may either be in the form of storage tanks, or a tank sewer of the necessary capacity. In most cases the latter is the better method of construction, as the sewer will clear itself of all deposit when the sewage is pumped out, and, in the majority of cases, storage capacity is more economically provided in this manner.

In designing and constructing sewers great care must be exercised in making them thoroughly watertight, not only to prevent the sewage leaking out and polluting the subsoil, but also to keep the subsoil water from finding its way in. When once the sewers are laid, leakages are very difficult to stop, and they cause additional expense at the purification works by reason of the increased flow that has to be dealt with. The authors have had experience in a town where, owing to lax supervision when the sewers were laid, enormous quantities of subsoil water leaked into the sewers, which at certain periods increased the normal flow of sewage by ten times. Under their advice the purification plant at the outfall works was considerably increased in size. Heavy expense was incurred in locating the leaks in the sewers, the method adopted being to float a lighted candle down the sewers on a plank with a cord attached, from manhole to manhole, when the leaks could be observed and the distances measured from the manhole. In the summer time, when the subsoil water was low, excavations were made at all points where the leaks had been observed, and remedial works carried out, with the result that the quantity of subsoil water admitted was greatly reduced. In numerous instances it was found that the leaks were caused by junctions left for house connections, these being improperly stopped by pieces of slate roughly cut to fit the openings and merely fixed with clay. It is advisable, in all new schemes, where the subsoil water rises at any time of the year above the sewers, to dispense with junctions, in order to avoid any such risk of leakage. When it is necessary to make connections with a sewer the pipes should be pierced, proper saddle pieces being fixed on them in cement; or if junctions are used, those with the stopper made in one piece of stoneware with the junction should be

adopted, the top of which may afterwards be removed when connections are required.

Frequently, owing to the configuration of the ground, it is necessary to lay some of the main outfall or intercepting sewers at great depths, and, if this should exceed 20 feet, it will generally be cheaper to tunnel than do the work by cut and cover. The authors have been engaged on tunnelling sewers as deep as 200 feet below the surface, and, provided the ground is of a suitable nature and free from water, there is no difficulty in driving a heading at this depth. Tunnelling is naturally expensive work, and should only be carried on under the most rigorous supervision, especially during the construction of the sewer and the filling in of the excavation; any laxity in this respect may cause the sewer to collapse and incur costly remedial works.

In nearly every case it will be necessary to leave the timber framing in the tunnel headings, and, if very loose ground is encountered, the heading should be filled up solid with concrete after the sewer is laid, and, where the streets are narrow and high buildings adjoin the sewer trenches, or where the ground is loose or of a treacherous nature, the struts, waling, and poling boards should be left in the ground permanently. This may appear a waste of money, but it is better than risking the destruction of adjacent property, which might fall if a settlement of the ground took place.

Wherever the sewers are laid, either in trenches or tunnels, in the main streets or through land, the trenches must be kept entirely free from water, if necessary by pumping, during the time that the pipes are being laid or the brickwork built, and until the cement has had a sufficient period of time to set and harden. Sewers cannot be constructed straight in line and gradient when laid in water, neither can the joints be well and truly made.

In all sewers the pipes or brickwork should be tested by completely filling them with water after the joints have set—and before covering them in—to ascertain if every portion of the work has been soundly constructed and is thoroughly watertight. Wherever sewer trenches are crossed by gas or water mains, a brick pier should be carried up from the solid ground to support them.

At all changes of direction and gradient, and wherever two sewers join, also on all straight lengths at intervals of 100 yards, manholes should be built of a suitable design. A cement concrete bed should form the foundation, half pipe inverts being embedded therein, and benchings of blue Staffordshire bricks built above the pipes to form a place for workmen to stand upon while attending to the sewers. The walls should be built with cement mortar, being arched over at the top to receive the covers, which should be of a heavy pattern and paved around with granite setts on the surface of the roadway. Cast-iron steps should be built in one of the manhole walls, in order to give access for workmen; and it is advisable to build in a stoneware flushing ring and provide a movable shutter and chain, so that each manhole can be used as a flushing chamber, by heading the sewage up in the sewer and manhole, two or three feet high, and then liberating it by pulling out the shutter by means of the chain. In addition to this, flushing chambers of from 600 to 1000 gallons capacity should be placed at the heads of sewers, and at other points where necessary, in order to remove any matters which may be deposited and tend to foul the sewers. In a scheme recently designed by the authors, the high price of town's water necessitated some supplementary means of flushing being adopted, and a special flushing chamber was designed to utilise the storm water. The apparatus shown in Plate 1 is of a simple

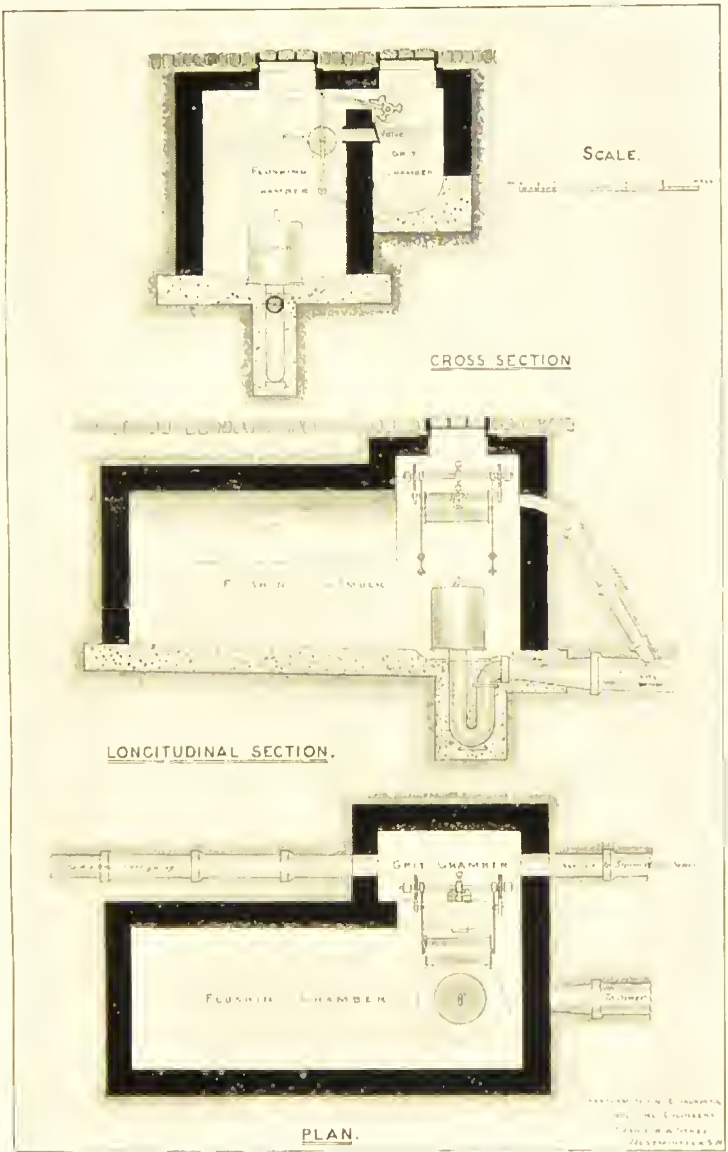


PLATE I.—Storm Water Flushing Chamber.

character, designed to allow the chamber to fill and then discharge, again fill and remain full until discharged by the sewerman, so that during a storm the sewers would be flushed once, the flushing chambers automatically retaining a second charge, to be used at a later period. It has been estimated that the installing of such an apparatus reduced the cost for flushing water by nearly one-half.

The ventilation of the sewers is a matter which requires very careful consideration. The air inlets and outlets must be designed and situated so as to induce currents of fresh air to travel continually through every portion of the sewers, in order to keep the whole system pure and prevent the formation of injurious gases. At the same time it is not necessary or advisable that such currents should be in any degree violent; in fact, a gentle current constantly flowing will afford far more effectual ventilation than a violent draught forced through the sewer at intervals; also a violent method of ventilation is liable to produce momentary pressure or vacuum at various points of the system, and a very small increase or decrease of atmospheric pressure is sufficient to unseal the usual pattern of waterseal, permitting a "flow-back" of sewer gas into dwelling-houses or other equally undesirable results. It is also necessary, in populated areas, to provide outlets for obnoxious gases in such situations as shall avoid all possibility of a nuisance or risk of disease being caused by the dissemination of bacteria. For this reason "open-grid" manholes should be avoided in proximity to dwelling-houses, though they may sometimes be used to advantage in country districts, provided due precautions are taken to prevent the road grit from entering the sewer in any large quantities. In populated areas the outlets should be carried well above the houses and any windows therein, and so placed that, whatever the direction

of the wind, no sewer gas can be carried into any dwelling. It is impossible to give, in a condensed form, anything like an exhaustive treatise on the subject of ventilation. Such information would be sufficient to fill a volume far too large for the time assumed to be at the disposal of our readers: and, moreover, practically every system of sewerage must be treated according to its own peculiarities, in order to obtain thorough and efficient ventilation, by which is meant a system of ventilation that will, at one and the same time, remove all obnoxious and injurious gases from the sewer, and convey them away in such a manner as to avoid any possibility of their contact with human beings.

In all schemes of sewerage some means must be provided for diverting the storm water into a water-course when it exceeds six times the normal dry weather flow. If the town is built on the banks of a river, several overflows can be obtained; but, in many instances, the whole of the sewage and storm water has to be discharged on the purification works before a suitable position for a storm-water overflow can be found. Various forms of storm-water overflows may be designed to suit the particular requirements, some being in the form of a leaping weir, others by the discharge of a pipe of known capacity; the most suitable form to adopt, however, being largely settled by local circumstances.

When the sewers and the disposal works are completed, consideration must be given to the connection of the private drains; and before any owner is allowed to connect, he should be compelled to deposit an accurate plan of the proposed drains, and obey regulations governing the method of connection, quality of materials, gradients, depths, and other things, to make certain that the work is done in a substantial and workmanlike manner. An able inspector should also

be appointed to supervise the work, test the drains, and carry out the regulations.

In all obnoxious trades, such as breweries, tanneries, dyeworks, fellmongers, etc., the liquid wastes of which would probably interfere with the purification process adopted, the owners should be compelled to put down purification works for treating the liquid trade waste, before permission is granted for a connection to be made to the sewers. Periodical examinations should be made by some official of the Board, to see that these plants are being worked in a proper manner and a satisfactory effluent produced.

Towns built on the sea coast, or at the mouth of tidal rivers, may sometimes dispose of their sewage by discharging it, without treatment, into the sea. Before doing this, it must be ascertained that it will not interfere with any fishery or oyster storage ponds. The designing of a sea outfall requires a complete knowledge of the tidal currents and rise and fall of the water during neap and spring tides. Diagrams should be made showing the heights of high and low water mark at spring, neap, and ordinary tides; float experiments being carried out to ascertain the direction of the flow of sewage if discharged into the sea at the proposed outfall. If a place of discharge cannot be obtained where the sewage is carried directly out to sea, but would be washed back upon the coast, it will be necessary to provide some works for its purification.

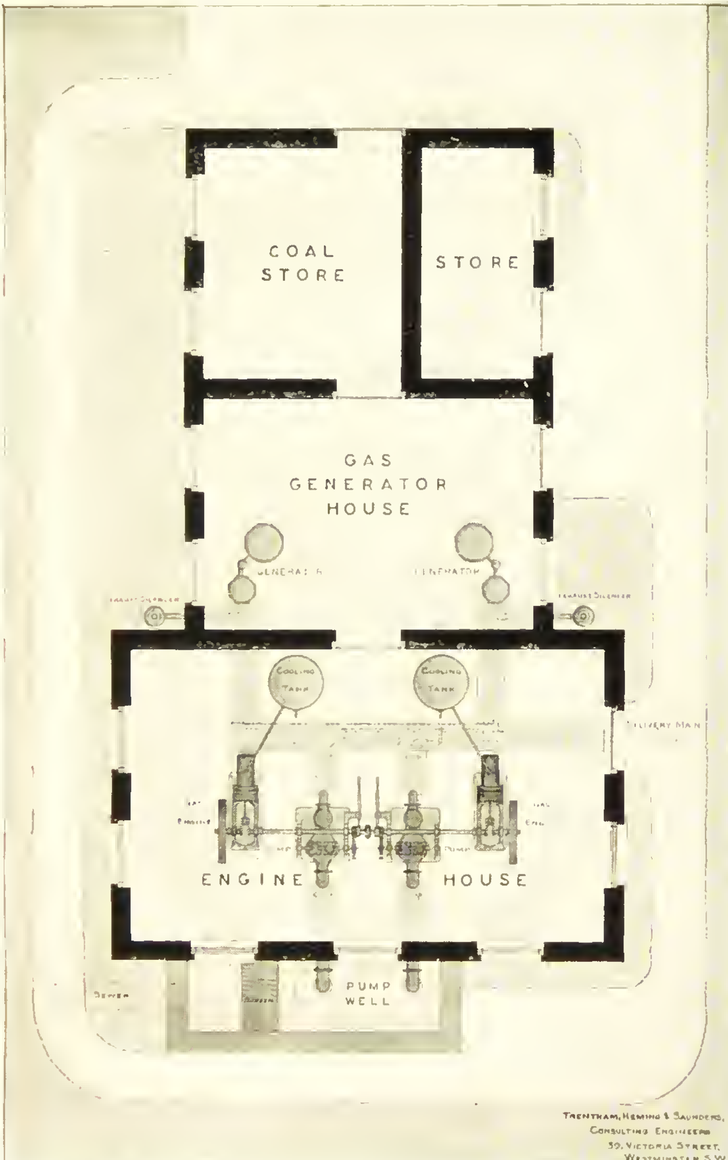
In some towns the septic tank has been adopted; but it is scarcely suitable for the purpose, the effluent being highly objectionable, and considerable quantities of sludge are produced which necessitate its removal at stated periods; both of these points, in a pleasure resort, being evils that should be avoided. A far better plan is to treat the effluent in aërobic slate beds, these producing an inodorous effluent

2

and obviating the sludge difficulty. In all sea outfall schemes, storage tanks or sewers must be provided to hold up the sewage until the proper time arrives for it to be discharged, which must only be on the ebb tide, so as to carry the sewage straight out to sea with no possibility of return.

In laying out a scheme of sewerage, a site to which the sewage can be conveyed by gravitation will generally be the most economical in capital cost; modern methods of sewage disposal, however, require a considerable fall, so that pumping is inevitable in many places. In some instances inverted syphons, judiciously designed, have enabled the sewerage to be successfully accomplished without pumping. These carry the sewage through low-lying land to the outfall site, where it rises to the requisite height in a manhole, from whence it may be carried forward to the purification plant. If this form of syphon be adopted it should have ample means provided for flushing out any deposit that may accumulate, and the gradient should be sufficient to scour it out in an efficient manner.

In some cases economical considerations of capital expenditure make it advisable, and in other cases local circumstances necessitate that the sewage be pumped, and this can be effected in a variety of ways. A main intercepting sewer may be carried from the town to the outfall works, and at that point the sewage lifted by suitable pumps driven by gas engines with suction gas plant, or town's gas, or by oil engines, or steam-driven plant. Plate 2 shows a suction gas plant, recently designed by the authors, adapted to pump the sewage of a small town, which is found very convenient in work, the charges for fuel and upkeep being exceedingly low. If the town to be sewered is already provided with electrical power, motor-driven pumps can be cheaply installed and worked at very little cost. Plate 3



PLAN.

PLATE 2.—Suction Gas Pumping Plant.

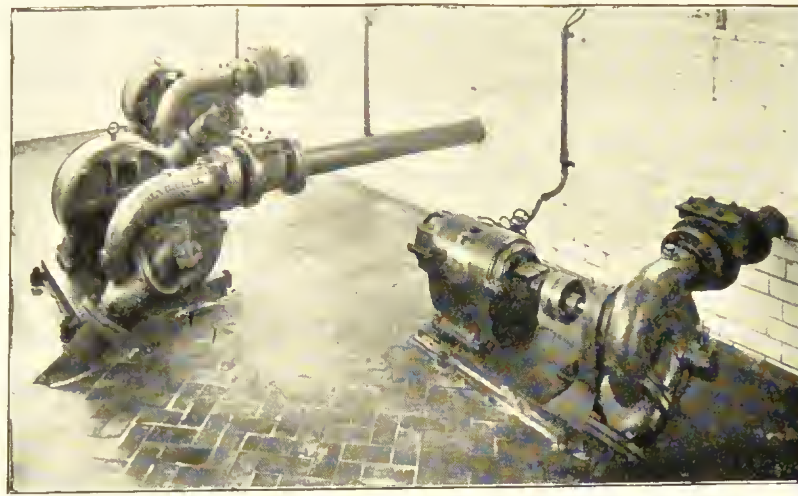


PLATE 3.—Electrical Pumping Plant

shows an installation at Chichester sewage works, of motor-driven pumps, of varying dimensions, in order that the fluctuations in the flow of sewage may be conveniently dealt with; the efficiency of this plant on trial was sixty per cent. In some towns, owing to the contour of the land and the large area to be dealt with, or to the sewage flowing into different water-sheds, it may be found necessary to pump the sewage at several points, electrically driven pumps being useful under these circumstances as they are economical to install, efficient in work, and have a low working cost. In combination with this a destructor for disposing of the house refuse of the district can be advantageously employed. Boilers and steam-driven electrical generating plant would be erected, the electrical energy produced being distributed through underground cables to various pumping stations in the town, where motor-driven pumps would be installed. These can be made to work almost automatically, requiring only the occasional visit of an attendant, to oil the bearings and adjust and clean the machines. A population of one thousand people would produce, on the average, about three-quarters of a ton of house refuse per day, this being sufficient to generate a quantity of steam, which, if utilised in a high-class compound engine, would give energy enough to produce some 18 to 20 horse-power for several hours each working day. If the sewage can be conveyed to the disposal works, and be there pumped, the heat from the destructor can be utilised to drive direct acting steam pumps. In each of the above cases some return would be made for the cost of destroying the refuse, which would otherwise be an additional burden on the town.

Another method of lifting the sewage from various points is by means of compressed air ejectors. An air compressing

station being erected on the sewage works, or at some other convenient position in the town, air mains would be laid from this to the different pumping points, at each of which an air ejector would be erected; and, so long as the air supply is maintained, the sewage will be lifted automatically into the high level sewer. This method of working has been laid down in many towns, and acts exceedingly well in practice; it is, however, costly to erect, and the low efficiency makes the working costs appear excessive.

II

POWERS AND DUTIES IMPOSED ON LOCAL AUTHORITIES BY THE LEGISLATURE

VARIOUS acts of parliament have given Local Authorities considerable power to deal with the sewerage of towns and villages, and it may be said that, for all practical purposes, the general law relating to sewage disposal in England and Wales is to be found in the Public Health Act, 1875, supplemented by the Public Health Acts Amendment Act, 1890, the various Acts relating solely to the Metropolis and the Rivers Pollution Preventions Acts.

Sewage works may be constructed either *within* or *without* the district of a local authority. As regards sewage works *within* the district, all the existing public sewers are vested in the local authority, which is given power to construct sewers on public highways or private lands, to compulsorily purchase land and erect works either for the treatment of sewage by natural or artificial means.

Section 32 of the Public Health Act, 1875, gives the local authority power to construct sewers or sewage disposal works *without* their district, and prescribes the mode of procedure:—

> " A local authority shall, three months at least before commencing the construction or extension of any

Notice to construct disposal

works *without* the district.

sewer or other work for sewage purposes *without* their district, give notice of the intended work by advertisement in one or more of the local newspapers circulated within the district where the work is to be made."

"Such notice shall describe the nature of the intended work, and shall state the intended termini thereof, and the names of the parishes, and the turnpike roads and streets, and other lands (if any) through, across, under or on which the work is to be made, and shall name a place where a plan of the intended work is open for inspection at all reasonable hours; and a copy of such notice shall be served on the owners or reputed owners, lessees or reputed lessees, and occupiers of the said lands, and on the overseers of such parishes, and on the trustees, surveyors of highways, or other persons having the care of such roads or streets."

By section 33 of the Public Health Act, 1875:—

Objectors to disposal works *without* the district.

"If any such owner, lessee, or occupier, or any such overseer, trustee, surveyor, or other person as aforesaid, or any other owner, lessee, or occupier who would be affected by the intended work, *objects to such work*, and serves notice in writing of such objection on the local authority at any time within the said three months, the intended work shall not be commenced without the sanction of the Local Government Board after such inquiry as hereinafter mentioned, unless such objection is withdrawn."

Section 34 of the same Act provides for such objections, and states that:—

Local Government

"The Local Government Board may, on application of the local authority, appoint an inspector to

make inquiry on the spot into the propriety of the intended work and into the objections thereto, and to report to the Local Government Board on the matters with respect to which such inquiry was directed, and on receiving the report of such inspector, the Local Government Board may make an order disallowing or allowing, with such modifications (if any) as they may deem necessary, the intended work." Board and objections.

Section 299 of the Public Health Act, 1875, gives power to the Local Government Board to enforce performance of duty by defaulting Local Authorities, as follows:—

"Where complaint is made to the Local Government Board that a local authority has made default in providing their district with sufficient sewers, or in the maintenance of existing sewers, or in providing their district with a supply of water, in cases where danger arises to the health of the inhabitants from the insufficiency or unwholesomeness of the existing supply of water and a proper supply can be got at a reasonable cost, or that a local authority has made default in enforcing any provisions of this Act which it is their duty to enforce, the Local Government Board, if satisfied, after due inquiry, that the authority has been guilty of the alleged default, shall make an order limiting a time for the performance of their duty in the matter of such complaint. If such duty is not performed by the time limited in the order, such order may be enforced by writ of *mandamus*, or the Local Government Board may appoint some person to perform such duty, and shall by order direct that the expenses of performing the same, Proceedings on complaint to Board of default of local authority.

together with a reasonable remuneration to the person appointed for superintending such performance, and amounting to a sum specified in the order, together with the costs of the proceedings, shall be paid by the authority in default; and any order made for the payment of such expenses and costs may be removed into the Court of Queen's Bench, and be enforced in the same manner as if the same were an order of such Court."

"Any person appointed under this section to perform the duty of a defaulting local authority shall, in the performance and for the purposes of such duty, be invested with all the powers of such authority other than (save as hereinafter provided) the powers of levying rates; and the Local Government Board may from time to time by order change any person so appointed."

Section 300 of the same Act gives further provision for the recovery of expenses, and under certain conditions

Further provision for recovery of expenses.

". . . . the Local Government Board may . . . . . . empower any person to levy, by and out of the local rate, such sum . . . . . . as may, in the opinion of the Local Government Board, be sufficient to defray the debt. . . . . . ."

Sections 15 and 16 of the Public Health Act, 1875, provide for the maintenance and making of sewers, and, as they have an important bearing on the matter, are given in full:—

Maintenance and making of sewers.

15. "Every local authority shall keep in repair all sewers belonging to them, and shall cause to be made such sewers as may be necessary for effectually draining their district for the purposes of this Act."

16. "Any local authority may carry any sewer through, across, or under any turnpike road, or any street or place laid out as or intended for a street, or under any cellar or vault which may be under the pavement or carriageway of any street, and, after giving reasonable notice in writing to the owner or occupier (if on the report of the surveyor it appears necessary), into, through or under any lands whatsoever within their district."

Powers for making sewers.

"They may also (subject to the provisions of this Act relating to sewage works *without* the district of the local authority), exercise all or any of the powers given by this section without their district for the purpose of outfall or distribution of sewage."

Section 17 of the Public Health Act, 1875, provides for the purification of sewage before being discharged into streams, as follows:—

"Nothing in this Act shall authorise any local authority to make or use any sewer, drain, or outfall, for the purpose of conveying sewage or filthy water into any natural stream or watercourse, or into any canal, pond, or lake, until such sewage or filthy water is freed from all excrementitious or other foul or noxious matter such as would affect or deteriorate the purity and quality of the water in such stream or watercourse, or in such canal, pond, or lake."

Sewage to be purified before being discharged into streams.

Section 28 of the Public Health Act, 1875, gives power to an authority to agree for communication of sewers with the sewers of an adjoining district, as follows:—

"The local authority of any district may, by agreement with the local authority of any adjoining district,

Power to agree for

communication of sewers of adjoining district.

and with the sanction of the Local Government Board, cause their sewers to communicate with the sewers of such last-mentioned authority, in such manner and on such terms and subject to such conditions as may be agreed on between the local authorities, or, in case of dispute, may be settled by the Local Government Board: Provided that so far as practicable storm waters shall be prevented from flowing from the sewers of the first-mentioned authority into the sewers of the last-mentioned authority, and that the sewage of other districts or places shall not be permitted by the first-mentioned authority to pass into their sewers so as to be discharged into the sewers of the last-mentioned authority without the consent of such last-mentioned authority."

Rivers Pollution.

The Rivers Pollution Prevention Act, 1876, is divided into six parts. Part I. makes it an offence for any person to put any solid matter, or any putrid solid matter, rubbish, or cinders, into any water-course. Part II. prevents any person from allowing any solid or liquid sewage matter to enter a water-course. Part III. prohibits the draining into water-courses of any waste matters from any manufactories or mines, the owners of which must show to the court that they are using the best reasonably available means to render harmless the waste liquids flowing into the water-courses. Part IV. deals with the administration of the law, and provides that sanitary authorities shall afford facilities to enable factories to drain into sewers. The sanitary authorities are given power to enforce the provisions of this act in respect of any stream passing in or through their district. The maximum penalty prescribed for causing an offence under this act is not to exceed fifty pounds per day

for every day that the offence continues. Parts V. and VI. apply to Scotland and Ireland only.

In the Local Government Act, 1888, the County Councils, in section 14, are given power to enforce the provisions of the Rivers Pollution Prevention Act, 1876. Powers of County Councils.

The Public Health Acts Amendment Act, 1890, is an adoptive Act only. It deserves mention, as it prohibits the discharge into sewers of chemical refuse, waste steam, etc. Chemical refuse.

The Rivers Pollution Prevention Act, 1893, makes it quite clear that the offence of permitting sewage to pass into a stream could be established against a sanitary authority, even though the sewers vested in the authority had been constructed before the passing of the Public Health Act, 1875. Pollution from sewers constructed prior to Act.

By a series of Acts the various authorities of the city and county of London are vested with special provisions for dealing with the sewerage of this area. City and County of London.

In the event of complaint being made to the Local Government Board as to a town being in default in respect to the sewering, the Board may take measures to compel the defaulting authority to sewer the town and dispose of the sewage in a satisfactory manner. The requirements of the Local Government Board in respect to the sewerage and sewage disposal are not officially published, and it is only by constantly noting the results of inquiries, and submitting schemes for their approval, that works can be designed which will meet with their sanction.

Where authorities have provided sewage disposal works, and a nuisance has been caused to some neighbouring property owner or resident, they run the risk of costly law proceedings and of losing enormous sums of money in the payment of legal expenses. Almost invariably the decision of the courts has been against the authority, excepting in

such cases where the works have been proved to be of the most up-to-date character. Considering these circumstances, local authorities would be well advised, when complaint of a nuisance is brought against them, to endeavour by every means in their power to come to an amicable settlement, and even to offer to reconstruct the works on the most scientific methods. In one case known to the authors nearly £10,000 was spent on a lawsuit which the local authority lost, and they were afterwards engaged to re-model the works at a further cost of £12,500, the alterations being so successful that the plaintiff afterwards voluntarily expressed his approval of the alterations and complete satisfaction with the results. Had the authority met the complainant in a friendly manner, no lawsuit would have taken place, and the authority would have saved themselves the cost of litigation.

III

SEWAGE PURIFICATION

THE various Acts of Parliament make it obligatory upon all local authorities, when laying down sewerage schemes, to purify the whole of the sewage before discharging it into any water-course. In sea outfalls, if the set of the tidal current will carry the sewage out to sea, without causing a nuisance to any person, or injury to any fishing rights, it may be discharged without treatment; but the authors' experience is that, in many towns on the sea-coast it is better to subject the sewage to some preliminary method of treatment in order to remove the grosser solids, excreta, paper, and other substances that are liable to cause a nuisance if washed ashore. The consensus of opinion in all communities at the present day demands a high sanitary condition, and it would be useless laying down any sewage purification plant which was not of the most perfect kind.

Tracing back the history of the disposal of sewage other than by discharging into the sea or a water-course, we find that land was at first the only means available for purification, and, though the facts were not known at that date, this process was no other than biological treatment in a crude form. Chemical knowledge afterwards devised many different processes for producing a clarified effluent; but, however successful the works—purifying sewage solely by

chemical means—were managed, a really satisfactory effluent could not be produced; the defects of this system of treatment being that the effluent is liable to secondary decomposition, a condition which can only be removed by filtration or oxidation on land. To supplement the chemical treatment, many forms of filters were used, but none achieved any very remarkable degree of success.

During recent years the study of biology and bacteriology has so much advanced that the whole process of purification of organic matters on land can be explained; and, furthermore, artificial beds can be constructed which will propagate the various forms of biological life necessary to produce the chemical changes required to convert an organically polluted water into a pure one.

The micro-organisms are generally classified into the "anaërobes," which thrive best in the absence of light and air, and the "aërobes," which thrive best with a plentiful supply of oxygen and light. Under perfect conditions it has been estimated by Cohn, "that at the end of twenty-four hours the microbes from a single individual would occupy one-fortieth of a hollow cube, with edges one-twenty-fifth of an inch long; but at the end of the following day they would fill a space of twenty-seven cubic inches, and in less than five days their volume would be equal to an entire ocean." This authority, of course, assumes that there would be nothing antagonistic to their growth, such a result not being possible under ordinary conditions; this statement, however, gives some idea of the prolific growth of the bacteria; and, as a practical illustration, the fermentation of yeast—which is caused by a micro-organic growth—will give some idea of the productiveness of the organisms under favourable circumstances. In artificial purification works, this prolific bacterial growth is fostered

in order to bring about the changes in the organic matters present in sewage. An ordinary contact bed is so arranged that when it is filled the organic matters in the sewage find a resting-place on the surfaces and interstices, and, after this has occurred, the water is run off. Air then finds admittance into the bed, with the result that the bacteria commence to multiply, and, in order to maintain their existence, feed on the organic matters, converting them into gases, inert substances, and dissolved residues. The foundations of the most modern methods of purifying sewage are entirely based on the productiveness of bacteria and biological life, and the works are so arranged that the growth of the micro-organisms is developed under the most favourable circumstances.

IV

LAND TREATMENT OF SEWAGE

PURIFICATION of sewage can be effectually carried out on suitable land, which should be of a light loamy, or sandy nature, with a sufficient thickness of top soil. It should be well underdrained, and the surface laid out so that the whole area can be evenly covered with a thin film of sewage. If clay land is used, the underdrainage should be omitted, as during the summer time this cracks and allows the sewage to pass into the underdrains without filtering through the soil. Land treatment, however, requires a considerable amount of care in working, and the ordinary sewage farm manager is too apt to think more about growing crops than the purification of sewage, though there can be no question that, from land of good quality, an effluent of a high degree of purity can be obtained. Clay, peat, and boggy land are quite unsuitable ; and if this only is available, some method of artificially purifying the sewage must be resorted to. Before applying the sewage to land, it is necessary that the floating particles should be screened out, and, in addition, the heavier suspended solids should be settled in a detritus chamber, as these substances, if continually placed upon the surface of the soil, tend to clog up the pores, making it difficult for the liquid to percolate. In some places a modification of land treatment may be resorted to, and the

crude sewage given a preliminary treatment, either in tanks or in aërobic slate beds, the latter method being the most effectual, as it disposes of the sludge difficulty, and the effluent is in a better condition for receiving oxidation on land.

When land is used as a *filtration* area—the sewage being of medium strength, and receiving a preliminary treatment, either by being mechanically settled in tanks, or purified in aërobic slate beds before passing on to the land—the amount of sewage that can be purified on the most suitable kinds of soil, viz., light sandy loam overlying gravel and sand, should not exceed 20,000 gallons per acre, and there should be a further surplus area of at least 25 per cent. On soils not so suitable, the volume of sewage per acre should not exceed 10,000 gallons, with a surplus area as before.

Where land is used for *surface irrigation*—the sewage being of medium strength, and receiving a preliminary treatment, either by being mechanically settled in tanks, or purified in aërobic slate beds, before passing on to the land—the amount of sewage that can be purified on the most suitable kinds of soil, viz., such as loam overlying gravel, should not exceed 4500 gallons per acre. On soils not so well suited 2000 gallons per acre; and on unsuitable soils 1000 gallons per acre; a surplus area of from 25 to 30 per cent. in all cases being required.

V

ARTIFICIAL PRIMARY TREATMENT OF SEWAGE

The difficulty in obtaining suitable land of adequate area for purifying the sewage of towns, and the complete failure of sewage disposal plants based entirely on chemical precipitation for producing an effluent, has mainly led to the development and perfection of artificial methods of purification.

The complex nature and different varieties of sewage found in the various towns and villages make it necessary that each place should be considered separately. If ordinary domestic sewage only is required to be treated, the problem of purification is easily solved; but in many towns liquid trade refuses, such as brewery, tannery, fellmongers, dye-works, and other manufacturing wastes, introduce complications, and it requires considerable experience in dealing with such substances to design a plant that shall produce a satisfactory effluent with a certainty of success.

In one town where the authors were called upon to advise the authority, the disposal works had to deal with 3,000,000 gallons of sewage per day, of which amount a large quantity consisted of refuse from breweries, tanneries, dye-works, and fellmongers. By carefully designing the works to deal with these conditions an effluent of a remark-

able degree of purity was obtained, and no nuisance or smell whatever was produced on the works.

In artificial purification plants it is usually necessary to divide the operations into different stages, the preliminary treatment being for the purpose of taking out the suspended solids and fitting the effluent for further oxidation in the biological beds. It is advisable, in some cases, to again subdivide the secondary treatment, and either pass the effluent over land or through secondary biological beds.

There are several methods of artificially treating sewage primarily: (1) By chemical precipitation; (2) by sedimentation; (3) by septic or anaërobic tanks; and (4) aërobically in biological beds. When the sewage first enters upon the works it is advisable to roughly screen out the grosser particles; after this it should be passed through detritus tanks to deprive it of the road grit, ashes, coal dust, and heavier suspended solids, all of which would be liable, if not removed, to interfere with the later portions of the process of purification.

(1) Chemical Precipitation.—In this method of primary treatment, it is necessary to construct tanks having a capacity of one day's flow of sewage. Before being admitted to the tanks the sewage receives a dose of chemicals, the particular precipitants mostly used at the present time being alumina-ferric, various iron compounds, and lime; all these have much the same effect, coagulating the suspended solids, and causing them to subside to the bottom of the tanks. The amount of purification, based on the reduction of the albuminoid ammonia, will vary from about 50 to 80 per cent., including the matters in suspension, which, however, settle mechanically, depending on the strength of the sewage and amount of chemicals used. The great objection to chemical treatment is the amount of sludge produced,

which is about thirty tons per million gallons of sewage treated; it necessitates, in large works, sludge pressing machinery, and in small works plots of land specially laid out for its disposal. Moreover, there is always a difficulty in getting rid of the dried sludge; and during harvest and other times, when farmers are busy, large accumulations take place at the disposal works, causing a considerable nuisance. From a sanitary point of view, the spreading of the micro-organisms contained in the sludge over large areas of land in the vicinity of towns, is a danger to health, and should not be allowed if other means of disposal are available.

In some towns it has been necessary to adopt chemical precipitation as a preliminary treatment, on account of the complicated character of the sewage, the peculiar trade wastes in these instances not being amenable to preliminary anaërobic or aërobic treatment.

(2) **Sedimentation.**—In this form of treatment the sewage is passed through tanks having a capacity of one day's normal flow, the only purification effected being that caused by the mechanical deposition of the suspended solids, which, owing to their heavier specific gravity, subside to the bottom of the tank when the sewage is brought into a state of quiescence. According to some authorities the effluent from a sedimented sewage is in a better condition for final treatment than is that from a chemical process or from septic tanks. The amount of sludge produced by sedimentation is about 20 per cent. less than by chemical precipitation, so that with this process there is still a very considerable amount of sludge to dispose of, and the remarks made respecting this under the first heading will also apply in this case. Plate 4 shows the tanks, designed some years ago by the authors, in course of construction at the city of

PLATE 4.—Tanks at Chichester Sewage Works, in course of construction.

PLATE 5.—Tanks at Chichester Sewage Works, completed

Chichester Sewage Disposal Works, and Plate 5 a view of the same when completed.

(3) Septic or Anaërobic Treatment.—This method of treatment has not altogether come up to the expectations of its enthusiastic advocates. When first the system was introduced, it was claimed that the action of the anaërobic bacteria would liquify the whole of the sludge. As time went on this was found to be incorrect, and now careful measurements reveal that only about 30 per cent. of the organic matters are liquefied; a further 35 per cent. being deposited in the tank require to be dealt with as sludge, while the remaining 35 per cent. are carried away in the effluent and pass on to the filters, tending to choke them up. It must be apparent that an effluent containing such a large amount of suspended solids—50 per cent. of which is inert matter—cannot be day by day placed upon filters without clogging up the pores and rendering the percolation of the liquid into the bed difficult.

In some experiments recently made by Mr Joshua Bolton, manager of the Heywood Corporation Sewage Works, to compare the results of a chemically precipitated effluent with that of an effluent from a septic tank, it was found that on the four hours' oxygen test the chemically precipitated effluent was 44 per cent. better than that of the septic tank, and the difference in the albuminoid ammonia figures is even more remarkable—50·7 per cent. more purification being effected in the chemically precipitated than in the septic tank effluent. In summing up, Mr Bolton says, that "Chemical precipitation and one contact produced an effluent which would give satisfaction to our River Authority, but septic tanks and one contact is quite unsatisfactory, and a second contact would be necessary before the effluent would be sufficiently pure to be discharged into the stream, thus

increasing the area of beds required for septic treatment to double that required for chemical precipitation. Then the extra cost of washing the beds must be taken into account. The beds dealing with the septic tank effluent were choking up so rapidly that we had to abandon the method, and I estimate that the life could not have been more than five years, whereas the beds dealing with effluent from chemical precipitation have been in operation over ten years, and still maintain a capacity of 31 per cent."

Septic tanks should not be used in the vicinity of a town, or near to any residence, because the process, relying entirely on the decomposition of the sewage (the tanks being merely a form of cesspool), liberates large quantities of foul-smelling gases into the atmosphere, carrying with them myriads of micro-organisms, and, in addition to the obnoxious odour being a nuisance to the neighbourhood, the pathogenic organisms are deleterious to the health of the district.

(4) **Aërobic Treatment in Slate Beds.**—Mr W. J. Dibdin, F.I.C., F.C.S., late Chemist to the London County Council, has devoted many years to the study of the biological purification of sewage, and it is entirely owing to his labours that the artificial purification of sewage has reached the high stage of excellence which it now holds, while the experiments which he conducted for the London County Council, and at the Sutton Sewage Works, have proved to the world that this method of treatment could be successfully pursued. Many years' experience in dealing with the question of sewage has enabled him to evolve the slate bed, which has now been in operation for a sufficient period of time to justify an opinion as to whether the claims which Mr Dibdin put forward can be substantiated. The authors who have investigated all processes of sewage disposal from an entirely impartial point of view have for a considerable time

had the working of the slate beds under examination, and they are therefore in a position to give an unbiassed opinion thereon.

As a preliminary form of treatment no method of disposal can compare with the Dibdin Slate Bed. The sewage is treated in the beds aërobically, a layer of air being retained on the under surface of the slates each time the bed is filled, thus supplying sufficient oxygen to foster the aërobic bacteria necessary in dealing with organic matters deposited on the surface of the slates. When the effluent from the beds is run off, the aërobic organisms, *i.e.*, bacteria, infusoria, worms, etc. multiply under favourable circumstances with such prolificacy that practically the whole of the organic matter in the sewage is entirely disposed of within a short period of time. Thus, the desideratum that sewage engineers have been seeking for many years has been attained, namely, the total elimination of the sludge difficulty.

There is a considerable saving in working costs of this system, the beds requiring no attention beyond the regulation of the inlet and outlet valves. The experience of Devizes with the beds which were put into action on September 12th, 1905, may be given as an illustration of their economy in work. In 2½ years, when the sewage was treated in tanks, 8500 tons of wet sludge were produced and pressed into 1700 tons of cake; this operation being productive of considerable nuisance, as well as being a danger to the health of the inhabitants by the dissemination of the germs in the sludge, which was distributed over a considerable area of land in the vicinity of the town. In a corresponding period of 2½ years, during which the sewage was treated on the Dibdin slate beds, only 50 tons of what may be called inoffensive earth has been produced. Compared with other forms of preliminary treatment, this result

is remarkable, for in the same period of time an anaërobic, or septic tank, would have been half filled with sludge of a very obnoxious character, while, if the sewage had been treated by sedimentation, there would have been about 6400 tons of wet sludge to dispose of, entailing considerable expense.

The effluent produced from the slate beds has undergone considerable purification; practically the whole of the solid matters being removed, and its chemical composition so changed that it may receive final purification in a simple manner.

Plate 6 shows the slate beds in course of construction at Malden. It will be seen that they are "horizontally cellular," instead of "irregularly cellular," as in the case of coke or clinker beds. The slate consists of *débris* from the quarries, and is to be purchased cheaply, the chief cost being the splitting of the slate, cutting up the cubes, and the labour in filling the beds. This latter operation requires considerable care, the cubes being placed directly over each other. The slates are about one-quarter of an inch thick, and vary from one foot to three feet superficial area, the blocks being about two inches high; this construction giving a water capacity, when new, of about 85 per cent., and no less than 66 per cent. after working for some years, this being double the capacity of an ordinary filter constructed of clinker or coke; hence, for the same capacity, the slate beds can be made with a cubic measurement of only one half that required for clinker beds, an appreciable item in first cost. When the beds are completed they have the appearance of Plate 7, which shows the slate beds at Devizes in work, the upper surface of the slates being sufficiently strong to sustain the weight of labourers and others.

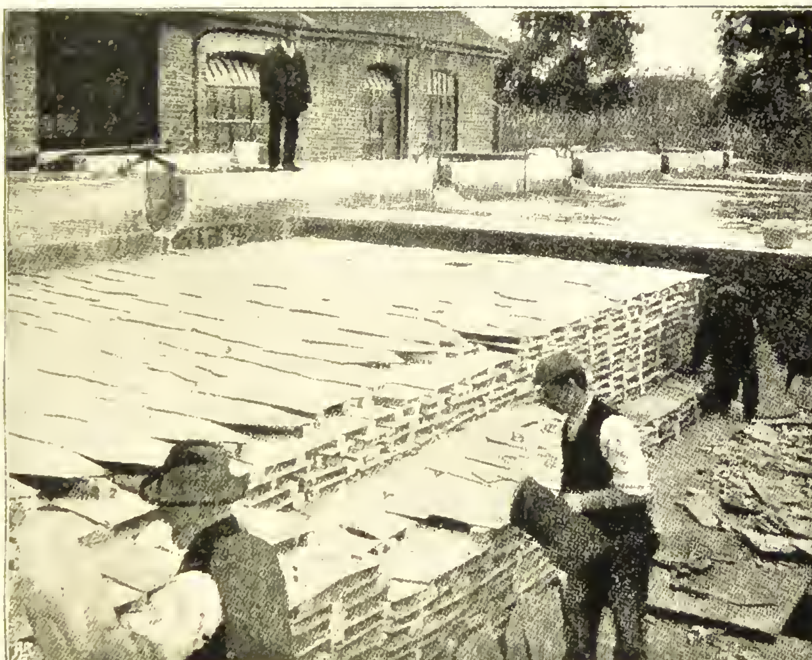


PLATE 6.—Slate Beds at Malden, in course of construction.

PLATE 7.—Slate Beds at Devizes.

VI

ARTIFICIAL SECONDARY TREATMENT OF SEWAGE

THE primary methods of purification already described do not produce sufficient change in the sewage to admit of its being discharged into a water-course or river, and a further process of oxidation must be carried out, either in contact beds, percolating filters, or on land. The treatment described removes a considerable portion of the suspended solids and organic matter, and leaves the effluent in a more or less unstable condition, so that the remaining organic matter and other impurities can be readily changed by the aërobic bacteria, which the secondary beds are designed to cultivate.

Contact Beds.—In this method of treatment a filter bed is either dug in clay land, as at Sutton, or formed with boarded sides, as at Oldham (neither of these systems being recommended except for temporary installations), or constructed with floors and walls of either brickwork in cement, cement concrete, or concrete faced with slates. If a loan is to be applied for from the Local Government Board, one of the last two methods of construction must be adopted. The beds must be underdrained, and provided with inlet and outlet valves, the sewage being distributed over the upper surface of the beds by means of wooden troughs,

glazed half pipes, or, as at Manchester, fine filtrant about six inches thick placed on the surface and hollowed out to form distributing carriers. This last method of distribution has the advantage of retaining a considerable portion of the suspended solids in the sewage, preventing them from percolating into the interstices of the bed. The body of the bed should be filled with a hard durable material to form the filtrant; coke, flints, granite, clinker, or other similar material, broken, screened, and washed, are all suitable substances from which good results may be obtained.

The area of contact beds must be sufficient to deal with twice the normal dry weather flow if the town is sewered on the "separate" system, or three times the dry weather flow if the town is sewered on the "combined" system. If the beds are hand worked, two fillings per day only must be given, with storage for the night flow; but if automatic inlet and outlet valves are installed, three fillings per day may be given to each bed. The number of beds will remain constant, six or eight should be the minimum quantity, so that they can be worked alternately; that is, when one bed is filled, the sewage should then flow into the next bed and so on until the whole of the beds have received their charge, the cycle again commencing at the first bed. In any case it is necessary to have a sufficient number of beds so that one or more of them can be thrown out of work, in order that it may have additional rest. The usual method of working a bed on the eight hours' cycle is to arrange for it to fill in one hour, rest full two hours, empty in another hour, and remain empty four hours for æration.

In many cases one contact will not effect sufficient purification of the sewage to enable it to be discharged into a water-course, and in such instances double contact beds are

sometimes constructed. These naturally require twice the amount of fall; but where this is available, it will be found advisable, instead of constructing double contact beds, to adopt continuous percolating filters.

The method of charging and discharging the liquid in contact beds can be effected either by hand-worked or automatic valves, in the former method a good disc valve being suitable. In schemes of sewage purification for small towns, where night men are not employed and the valves hand worked, it is necessary to provide storage for the night flow of sewage, and only give the beds two fillings per day against three fillings per day when fitted with automatic valves.

There are many different types of automatic valves for contact beds, the object of all being to work the beds in the proper cycle. The filling of one bed, opening the valve of the next bed, and so on in rotation, until all of the beds have been charged, when the operation commences again, provision being made for allowing any of the beds to be rested for an extended period. In some installations of automatic valves, when the bed is full, the liquid overflows into a drum which falls and actuates a lever, closing a valve to that bed and opening the inlet to the next bed. The discharge from the beds is regulated by a time valve, which comes into operation directly the bed is full, holding up the sewage for the necessary period of contact. The valve is actuated by the liquid filling a drum, which falls when there is sufficient weight to overcome the pressure on the outlet valve, and it consequently opens.

Another method of charging and discharging contact beds is by means of air-locked syphons which automatically feed the beds from the inlet carrier; and when the first bed is full, the liquid overflows and brings into operation the syphon in the

second bed, which then fills, and so on in rotation until the whole of the beds have been charged, the discharge from the beds being effected in a similar manner.

Plate 8 shows a view of an installation of contact beds which the authors have recently designed. These receive the effluent from the primary beds shown on the upper level of the land, the effluent from the lower contact beds being distributed over an irrigation area before passing into the stream on the lower boundary of the site. The beds are worked with automatic valves, and the working expenses of the scheme will be extremely low.

Percolating or Continuous Trickling Filters.—The best means for carrying out the secondary purification of sewage is by means of percolating filters. In this form of filter the effluent from the primary tanks, or slate beds, is evenly distributed over the surface of the filtrant by some mechanical means. The beds should not be less than 4 feet deep, and, in addition to this, the means of distribution require a further 15 inches head, so that it may be reckoned roughly that a continuous filter cannot be installed at a less depth than 5 feet 6 inches. A depth of 6 feet for the filtrant gives exceedingly good results, any depth beyond this can hardly be considered worth the expenditure necessary to procure it; and the better way, if a very highly purified effluent is required, is to install a secondary series of filters, at a lower level, upon which the effluent from the primary filters can again be distributed.

The area of percolating beds should be based upon the total amount of flow which they are intended to purify, *i.e.* in schemes approved by the Local Government Board (three times the normal dry weather flow in combined schemes, and twice the normal dry weather flow in separate schemes), at the rate of 56 gallons per square yard per foot

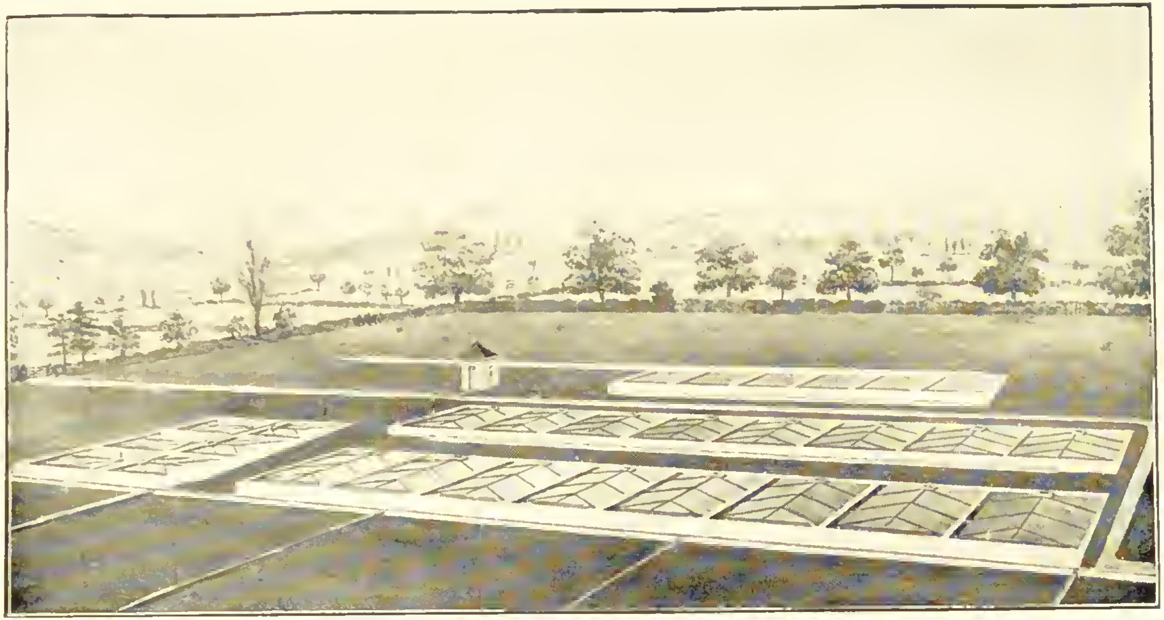


PLATE 8.—Installation of Contact Beds.

PLATE 9.—Percolating Filter at Chichester.

of depth, if followed by land treatment, and half this quantity if artificial filtration alone is relied on.

The circular percolating filter has been most used in this country, various methods of construction being adopted. In some cases the filters have been sunk in the ground, the excavations being lined with concrete and the filtrant filled on to the top of an aërating floor, which drains the purified liquid rapidly away. A variation of this form of filter is the type embanked above the ground, as shown by Plate 9, which is one of the bacterial filters carried out by the authors for dealing with the sewage of the City of Chichester. It is three-quarters of an acre in extent, the average depth of the filtrant being 5 feet 6 inches. Sea shingle, broken, washed, and screened, of varying grades, is used for the filtrant. Although the sewage of this town has large quantities of waste liquids from a brewery, tannery, and dye-works, in addition to the ordinary domestic sewage, the effluent produced is of remarkable purity, the following analysis giving the result:—

ANALYSIS OF EFFLUENT FROM CHICHESTER SEWAGE WORKS.

	In parts per 100,000.
Chlorine	4·26
Nitrates	·50
Dissolved oxygen : c.c. per litre . .	7·20

The filter was lined with cement concrete, the sides being embanked and sown with grass seeds. The revolving spreader is of very large dimensions, being 200 feet in diameter, and capable of dealing with a million and a quarter gallons of sewage per twenty-four hours. The spreader is electrically driven, a motor being fixed at the

outer ends of the two arms, which are supported on carriages running on a circular track outside the filter bed. The supply is controlled by an automatic measuring valve. The distributor was made by Messrs Mather & Platt, Limited, Salford Ironworks, Manchester, and is well designed, constructed in a very substantial manner, and performs its work efficiently, evenly distributing the effluent over every portion of the filter, the electrical current taken being exceedingly small even during gales of wind.

Filters without enclosing walls have been advocated by many engineers, and they no doubt secure efficient aëration; but owing to the additional quantity of filtrant necessary to form a natural slope, and consequently a floor area of greater extent, they cost about £250 more per acre to construct. Moreover, particles of the filtrant are continually falling into the surrounding effluent carrier.

The best way of constructing a percolating filter is to build it above the ground with walls constructed honeycombed of blue bricks laid in cement, having a concrete floor, with ample fall, to secure rapid discharge of the effluent.

An aërating floor should be constructed to all filters, this being a perforated platform, a few inches above the under concrete draining floor, and may be formed of ordinary flat tiles or slates, supported on bricks, but it is better to use one of the patent aërating floor tiles, several good designs of which are now to be procured. These tiles should extend through the enclosing walls, so that a rod can traverse the opening, or a strong jet of water be used to flush away the burnt-out humus settling on the draining floor. This form of construction provides for a ready flow of the effluent from the filter, without clogging up the lower layers of the filtrant, and is of great service in supplying

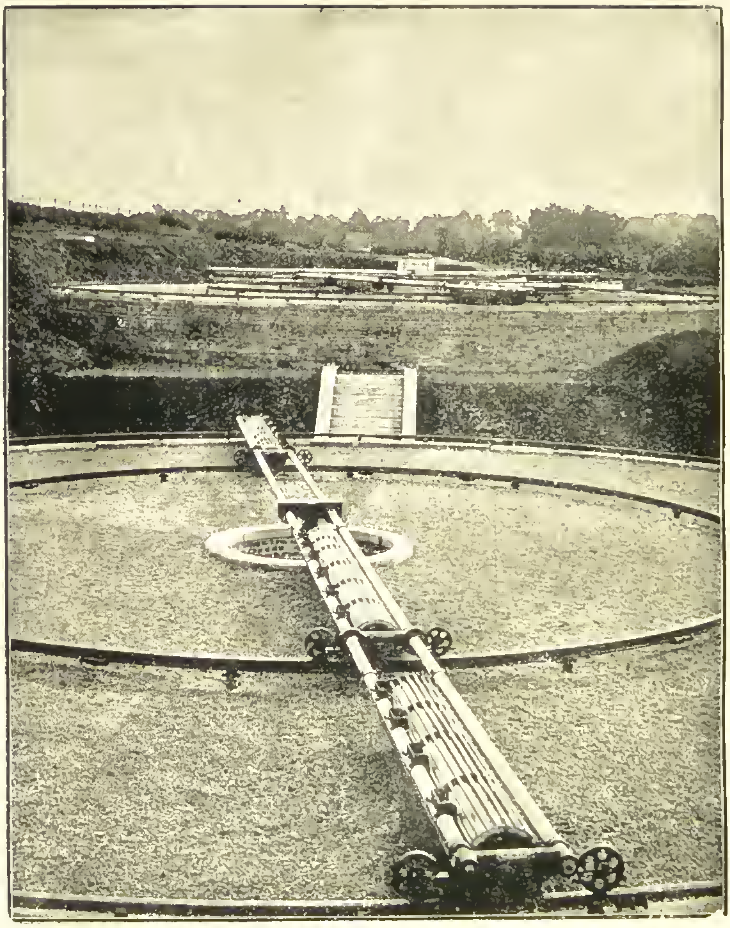


PLATE 10.—Fiddian Sewage Distributor.

biological life in the filter with the necessary quantities of oxygen to promote its growth. The filtrant should be placed upon this platform, and must be perfectly clean and graded to the requisite size to obtain the best results. Some difference of opinion exists as to what is the proper size of the filtrant, some advocating coarse particles, and others extremely fine particles; the former system requires a deeper filter, if the same degree of purification be required, than the latter system. The authors' experience is that a filtrant graded as follows gives good results: The bottom layer of 12 inches in thickness should have 2-inch particles, then a layer, 2 feet thick, of 1-inch particles, with a further foot of $\frac{1}{2}$-inch particles, the top foot being of 1-inch particles, making 5 feet in all. By placing the fine particles beneath the surface, the sewage freely enters into the body of the filter without ponding, the suspended solids being retained by the coarser particles on the surface of the filtrant.

The medium for filtration may be composed of similar materials as described for contact beds, broken clinkers probably giving the best results, and, as a rule, this can be cheaply obtained, being a waste material in most parts of the country. Percolating filters may be constructed either round, square, or rectangular, the type of distributing gear determining the shape. Plate 10 shows an installation of three "Fiddian" sewage distributors, each 63 feet in diameter, erected at Bushbury, near Wolverhampton. The depth of each filter is $4\frac{1}{2}$ feet, the sewage at this place being very concentrated. The sprinklers were supplied by Messrs Birch, Killon & Company, Manchester, and it is claimed that they are perfectly automatic even in a strong wind, and will sprinkle evenly any varying rate of flow without special dosing apparatus, and, however small the rate, liquid never

falls on the filter without the distributor moving onwards. The sprinkling is accomplished by means of the revolving water wheel, so that small holes are entirely dispensed with and consequent choking up, the even sprinkling in very small doses enabling shallow filters of finer material to be employed with a saving in cost and working head.

A type of automatic distributor largely used for distributing sewage over rectangular filter beds is shown by Plate 11. It is made by Messrs Ham, Baker & Company, Limited, Westminster. The apparatus is so arranged that the sewage is equally distributed over the whole area of the bed, on alternate sections of the filtering material, one half being dosed as the distributor works forward, and the other half as it returns, thus giving a period of rest after each feeding. It runs on rails, and is fed with the sewage from a trough at the side, being automatically syphoned into the supply pipes and conveyed to the drums of the apparatus, these being made in the form of a water wheel, revolve when charged with sewage, and at the same time propel the machine over the bed. The length of the beds on which these distributors travel should be from four to six times their width. This apparatus is in use at the sewage works at Wednesbury, Bolton, Kettering, and a number of other towns.

For rectangular beds, spraying jets are frequently used. They require a head of from 4 to 6 feet. If the latter head be available, each jet will distribute over a diameter of 12 feet. Plate 12 shows an illustration of Adams-Hydraulics, Ltd., spraying jets, for covering circular and square areas, the latter jet having the advantage of covering the whole area of the surface of the filter and not wasting any portion, as is done with the round jet.

There is a limit to the size of a revolving distributor

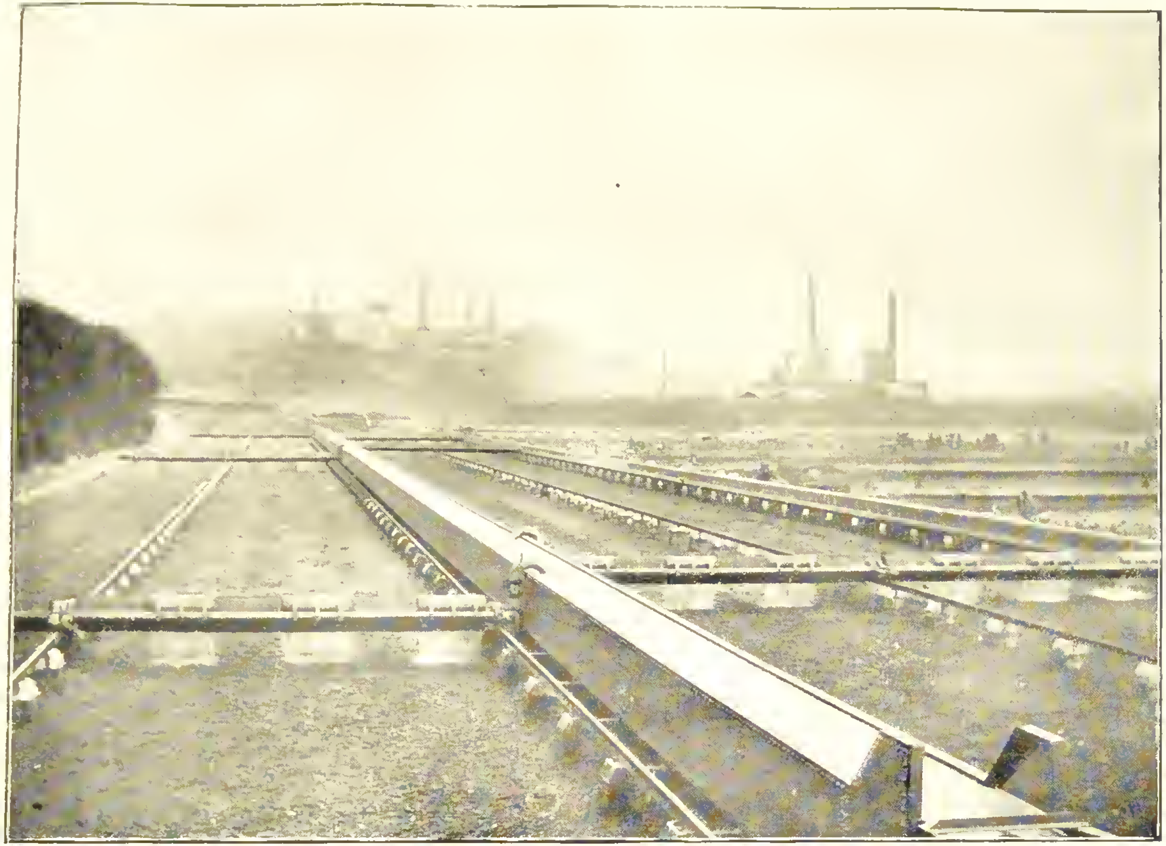


Plate II.—Sewage Distributors for Rectangular Beds.

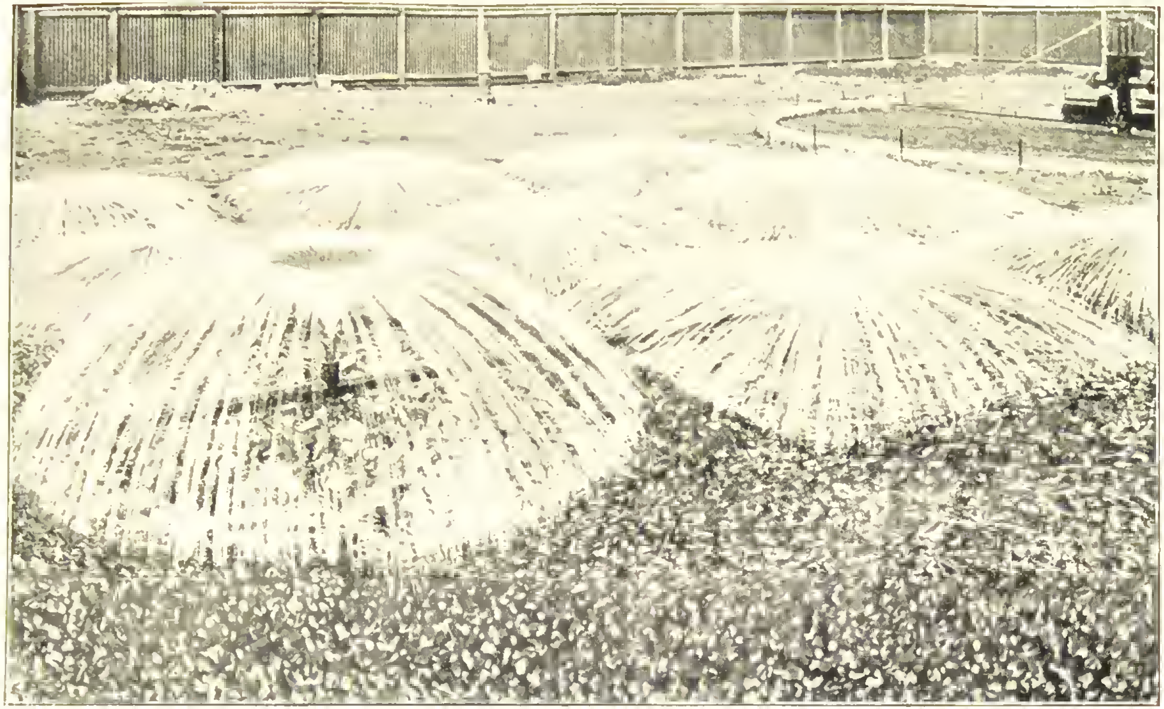


Plate 12.—Spray Jet Sewage Distributors.

working with the flow of sewage as a motive power. On circular filters the authors' experience is that the diameter should not exceed 120 feet. Distributors of a larger size than this are retarded by the wind, and it is frequently difficult to secure their rotation. If it is necessary to adopt spreaders of a greater diameter than this, they must be driven by some independent power, either by an electric motor, an oil engine, or gas engine. The power required for this purpose is very small, and adds little to the annual working costs.

Too great care cannot be exercised in selecting a suitable distributor for the sewage on percolating filters, and experience of working existing apparatus is of some value; a badly-designed or ill-constructed distributing apparatus will give endless trouble, and cause considerable expense every year for repairs and maintenance.

If the effluent from a percolating filter is afterwards treated on land, the burnt-out humus will be settled thereon and ultimately form a portion of the soil. In places where artificial treatment alone is relied on, settling tanks, or some form of straining filter constructed of sand and gravel, must be laid down to deal with this humus, as otherwise it would cause trouble with the River Boards if admitted into a stream. The humus is innocuous, but the presence of any suspended solids in an effluent from a sewage works would be sufficient to condemn it. The better way of getting rid of this burnt-out ash is to have a small deep tank, in duplicate, through which the effluent from the filter should flow, and be brought into a state of quiescence. The humus would then settle to the bottom, the effluent being drawn off at the top.

Management of Filters.—A few words on the working of filters may be of some assistance to those interested in the satisfactory performance of sewage purification plants.

Every portion of the surface of the filtrant should receive the same quantity of sewage. Each day every percolating filter should have a stated period of rest, and contact beds should have the rest periods assigned to them by the cycle of working, and occasionally all filter beds should be given an additional week's rest. A plentiful supply of air is necessary to the interior of all filters; and in order to insure this, the upper pores of the filtrant should be kept open, either by means of a long pronged rake, or digging with a fork. Analyses should frequently be made to show the amount of suspended matter in the sewage distributed on the filter, as, if this be excessive, it will tend to clog up the interstices and destroy the filtration. If the amount of suspended solids is found to be excessive, some alteration should be made in the primary treatment so as to retain the solids or dispose of them in a better manner. The effluent from the filter should be regularly tested to ascertain the amount of nitrites and nitrates. If the nitrite increase and the nitrate decrease, it will show that the filter is being overworked, or losing capacity, and in either case it should be given a prolonged period of rest. The burnt-out humus sometimes collects in the bed and retards the rate of filtration. Considerable quantities of this can be removed from filters having medium coarse particles by the application of jets of water. The spreader may be held in one position to effect this, and in a few minutes it will completely clear the burnt-out humus from the portion of the bed where it is held stationary. By performing this operation at frequent intervals all over the filter, the humus can be removed to a very large extent; and, after the filter has been cleared, the spaces between the draining floor and false floor should be thoroughly washed out with water from a hose-pipe, the whole of these washings being run on to a plot of land and

allowed to filter through it before discharging the effluent into the outfall. In towns where there are breweries connected to the sewerage system, care should be taken that excessive quantities of sour beer are not discharged into the sewers. The authors know of two cases where the whole of the bacterial action in filters at large sewage disposal works was deranged for some weeks, in consequence of such discharges. The acid in the beer entirely destroyed the bacteria which bring about purification, and caused acid forming bacteria to develop.

The mechanical part of the filter should be regularly attended to, the valves and bearings being oiled, packed, and adjusted from time to time, all the ironwork and steelwork being well painted to preserve it.

VII

STORM-WATER FILTERS

The Local Government Board require in sewage disposal works designed on the separate system twice the normal dry weather flow treated as sewage proper, a further four times the dry weather flow being treated either on storm-water filters or on land laid out for this purpose. In towns in which a combined system of sewerage has been adopted, three times the dry weather flow must be treated as sewage proper, and a further three times either on storm-water filters or on land. Not more than 500 gallons per square yard per day must be allowed for in the storm-water filters; and, if land be provided, the rate of filtration must not exceed 30,000 gallons per acre. Storm-water filters may be as shallow as two feet deep; but, if a loan is required, the Local Government Board will insist on their being permanently constructed with cement concrete floors, the walls being either built with a similar material or with brickwork in cement. The area of the filters should be divided into a number of beds, and be provided with the necessary inlet and outlet valves. They may be used either as contact beds, as adopted by the authors at Chichester, as shown by Plate 13, or they may be worked continuously.

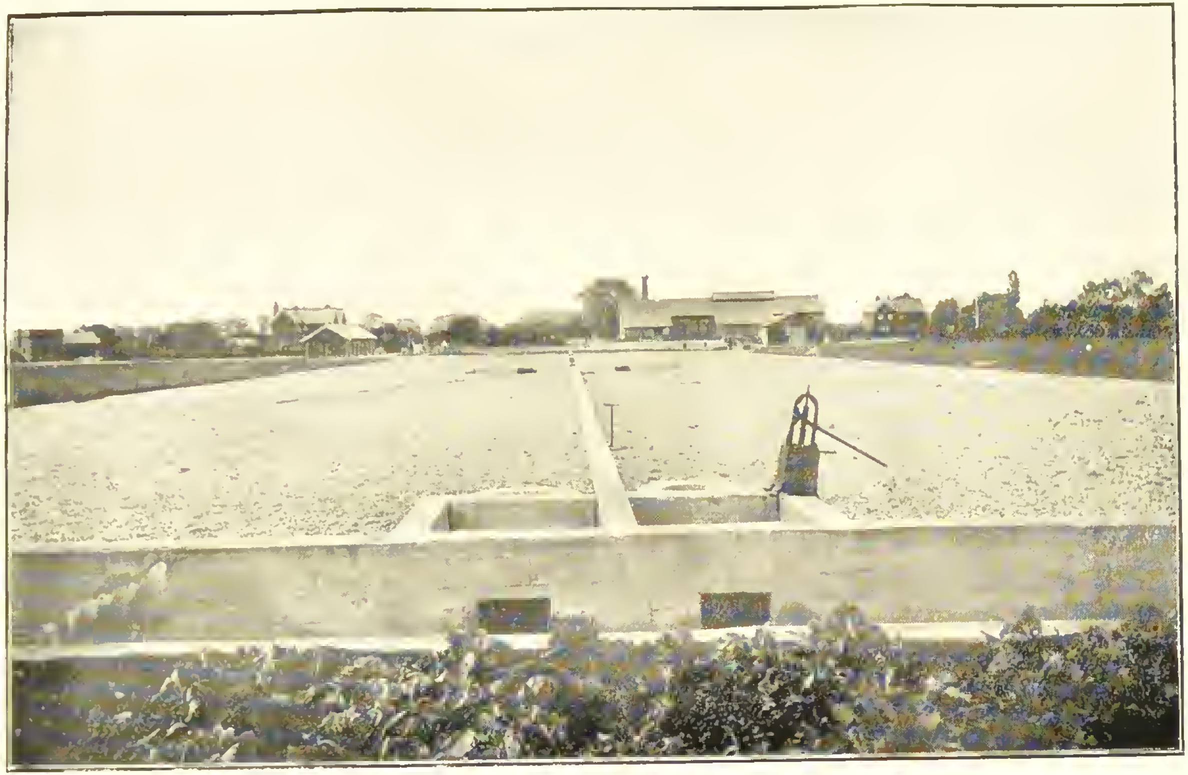


PLATE 13.—Storm Water Filters.

VIII

THE IDEAL METHOD OF TREATING SEWAGE

The ideal method of treating sewage is to carry out the whole of the operations without causing appreciable nuisance either on the works or in the vicinity. The sludge must be entirely destroyed, and the danger avoided of disseminating disease by spreading the pathogenic germs contained in the sewage over inhabited parts of the country. The working expenses of an ideal system of sewage disposal must be low, and the upkeep and maintenance required to keep the works in the most efficient condition should necessitate but a small amount of labour. Above all, the effluent sent out from the works must at all times be clear and sparkling, so chemically and bacteriologically pure that there will be no possibility of any stream being fouled, or water-course polluted, causing danger to human beings or animals drinking the water into which the effluent runs.

It is seldom in practice that the ideal can altogether be obtained; and in sewage disposal works, as in other matters, the best knowledge of the present day falls a little short of this. The authors have delineated what they believe to be the nearest approach, as yet possible, to an ideal sewage works, and think that it may be useful to lay before the reader a description of a scheme which they have recently

prepared for dealing with the sewage of a town of 6000 inhabitants. In this case it was necessary to pump a portion of the low-lying district, the sewage had to be disposed of in the most perfect manner possible, and, in addition, the house refuse destroyed. A suitable plot of land was selected about a mile and a half away from the town, to which the sewage was conveyed—five-sixths by gravitation, and one-sixth by pumping. For destroying the house refuse, a destructor was designed, which raised steam in two Cornish boilers, the whole being adapted to burn the refuse without creating any obnoxious fumes or dust. The steam generated by the refuse destroyed was converted into electrical energy, and transmitted along underground cables to the points where the sewage required to be pumped, high efficiency motor driven, centrifugal pumps being employed for this purpose. The sewage, upon entering the works, was first screened, then passed through a detritus chamber, the refuse from both of these places being mixed with the house refuse and destroyed in the destructor. After leaving the detritus chamber, the sewage then passed automatically into a series of six aërobic slate beds, in which the formation of the sludge is entirely avoided, the effluent from these being in a condition to receive further treatment, which is carried out on eight continuous percolating filters, arranged on two levels, so that if one filtration did not produce an effluent of the highest quality, it could again receive a further filtration. For dealing with storm water, eight filters, fitted with inlet and outlet valves, are constructed on the lower portion of the site, to be used as contact beds.

Plate 14 shows a general view of the works, the slate beds being on the higher portion of the ground, the first and second percolating filters in the centre, and the storm-water filter beds on the lower portion of the ground; below these

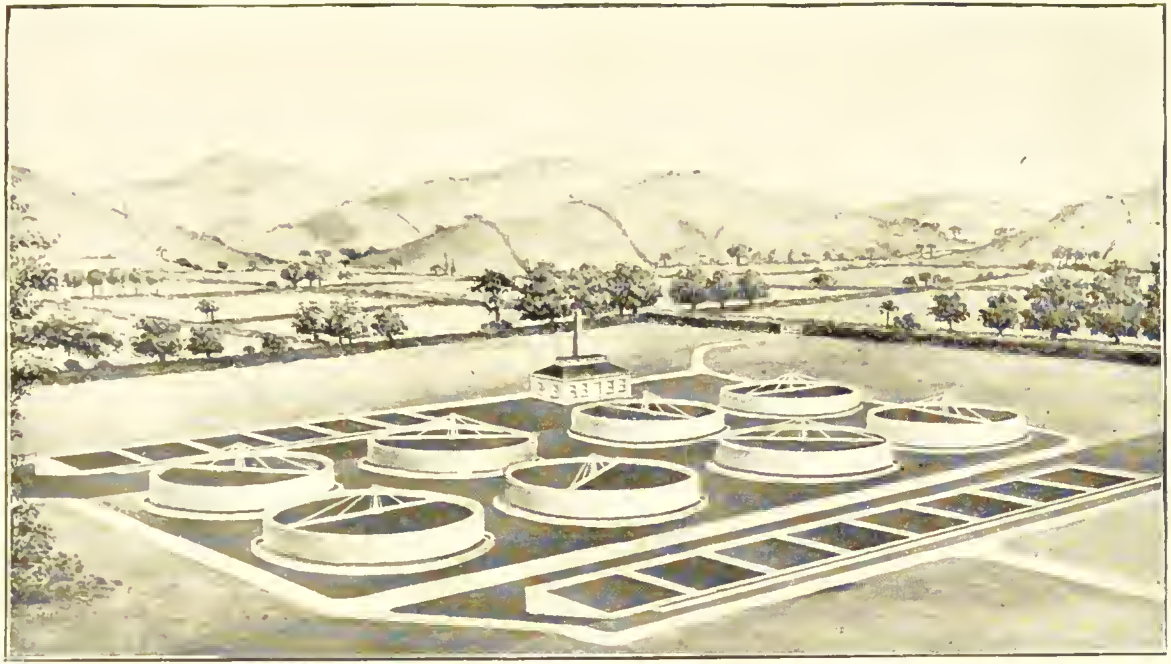


PLATE 14.—A Modern Sewage Disposal Works.

being the destructor, boiler house, and electrical generating plant. With this scheme there can be no nuisance, the only time when the sewage is exposed being when it is passing through the screen and grit chamber. From the slate beds there is no objectionable or harmful smell whatever, the level of the sewage being below the top layer of slates; and the process, being an aërobic one, precludes the formation of any obnoxious gases, as is the case when anaërobic processes are adopted for the primary treatment. The effluent from the slate beds has a slight earthy smell, and its distribution over the percolating filters is not attended with any unpleasant odour. The final effluent is clear and sparkling, and although not perhaps quite up to the standard of drinking water, it would cause no pollution whatever even if admitted into sluggish running water.

IX

CONCLUSION

In producing this little book, the authors have striven to throw, in a brief and concise manner, some light on the most modern methods of sewage disposal, and to simplify, to the lay mind, the complications which arise in the discussion of the question of sewering towns and villages, also to show that such works can be carried out without nuisance to the public or to owners of property adjacent to the disposal works, and without detriment to the health of the community.

The authors also hope that the extracts given of sanitary law will be of some service to local authorities, assisting them to avoid that constantly occurring, and serious, fault of accepting schemes not properly designed to meet full legal requirements, which considerably increase the original estimated expenditure.

If the information provided herein will materially assist only a few authorities to solve the problem of sewage disposal, and to make it an innocuous and inodorous process, as it should be, the authors will feel that their labours have not been altogether in vain.

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